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(54) **Arc Welding Device with a Resonant Circuit**

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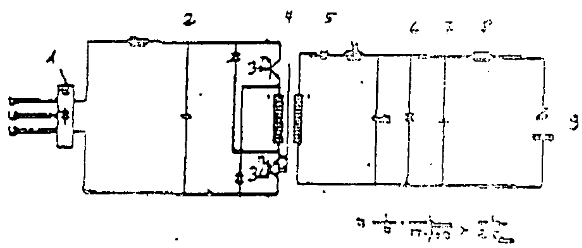
(57) The invention concerns an arc welding device consisting of an inverter current source with a line-voltage-powered rectifier 1, an intermediate circuit 2, a current transformer 4 that is switched at the input end and a rectifier 5 which is on the output end of the current transformer 4 and to which a welding device 9 is connected, where the current transformer 4 is switched by semiconductor switches T1, T2 which are electrically conducting during a predetermined switching interval T_{ein}. The switching

frequency of the current transformer 4 can be increased on the basis of added switching losses by providing a resonant circuit L_R, C_R for the switched current transformer 4, where the resonant frequency f_R of the resonant circuit is related to the predetermined switching interval of the semiconductor switches T1, T2 according to the following equation:

$$f_R = \frac{1}{2\pi\sqrt{L_R C_R}} > \frac{1}{2\, t_{ein}}$$



Description

The invention concerns an arc welding device consisting of an inverter current source with a line-voltage-powered rectifier, an intermediate circuit, a current transformer that is switched at the input end and a rectifier on the output end of the current transformer, with a welding device connected to the latter rectifier, where the current transformer is switched by the semiconductor switches which are electrically conducting during a predetermined switching interval.

An arc welding device of the type characterized initially is known from German Patent 4,128,175, where the device has an inverter current source to supply power to the welding process. It is desirable to operate such an arc welding device at the highest possible switching frequency of the current transformer. However, this is limited in practice by the fact that switching losses occur with each switching operation in the semiconductor switches. Therefore, these switching losses are proportional to the frequency, so increasing the frequency is equivalent to increasing the switching losses.

The object of this invention is therefore to improve on a device of the type described initially such that it can be operated at a higher switching frequency.

This object is achieved according to this invention by the fact that a resonant circuit which is provided for the switched current transformer has a resonant frequency whose relationship to the predetermined switching interval of the semiconductor switches can be expressed by the equation:

$$f_R = \frac{1}{2\pi\sqrt{L_R C_R}} > \frac{1}{2 t_{ein}}$$

The invention is characterized in that the known inverter current source is expanded by a resonant circuit whose inherent frequency is such that the current flowing in the resonant circuit or the voltage applied to it reaches zero before the next switching operation takes place in semiconductor switch T1 or T2. Due to the fact that one of the two parameters, the current or the

voltage, is zero at the switching point of the transistor, the switching losses are also zero at this time. This means that the arc welding device can be operated at a higher current transformer frequency. Another advantage is that the EMC interfering radiation is greatly reduced because transistors T1 and T2 are switched off either at I = 0 A or U = 0 V, so there is no di/dt or du/dt. It does not matter according to this invention whether the resonant circuit is located on the input or output side of the current transformer. The frequency correlation with respect to the switching interval of the semiconductor switches of the current transformer is important according to the conditions defined above.

One conceivable variant would be to use either a current resonant circuit, where the semiconductor switches are switched when the resonant circuit reaches zero, or a voltage resonant circuit where the semiconductor switches are switched when the voltage on the resonant circuit has reached zero.

IGBTs are suitable semiconductor switches to implement the welding device according to this invention because the frequency-dependent losses are otherwise significant with switches of this type.

Another special embodiment of this invention provides that the inductive element of the resonant circuit is formed by the leakage inductance of the current transformer. This results in a simplification of components because only one capacitor must be added to form the resonant circuit.

The solution according to this invention can be implemented for all types of current transformers, e.g. for single-ended transformers, double forward converters, bridge converters or half-bridge converters.

The invention is explained below in greater detail with reference to one embodiment which is illustrated in the figures, which show the following:

Figure 1 shows a schematic diagram of an embodiment of an arc welding device according to this invention.

Figure 2 shows signal characteristics to illustrate the

functioning of the circuit according to Figure 1.

Figure 1 shows a rectifier 1 that supplies power to a capacitor 2 that forms an intermediate circuit across an inductance that is wired as an intermediate circuit. Intermediate circuit 2 in turn supplies power to a downstream current transformer 4. Current transformer 4 is switched at the input end by semiconductor switches 3a, 3b such that a clock frequency in the medium frequency range (25 to 100 kHz) is formed at the input end.

At the output end, current transformer 4 is connected to a rectifier diode with a downstream resonant circuit consisting of a series inductance L_R and a parallel capacitor C_R.

A free-wheeling diode 6 is arranged parallel to the resonant circuit capacitor C_R. A welding device 9, which is represented in the figure by a welding electrode and a ground terminal, is connected to the output of the resulting inverter current source across a capacitor 7 and an inductance 8.

The semiconductor switches T1 and T2 (3a, 3b) are driven by triggering devices (not shown). The square-wave control signal for semiconductor switches T1 and T2 is shown in the top diagram in Figure 2. The pulse diagram indicates that the square-wave pulse has a certain width that corresponds to the switching interval of the semiconductor switches T1, T2 that are preferably designed as IGBTs. Outside of the switching intervals, the control signal for transistors T1, T2 is limited to the low level of the base voltage.

The characteristic shown in the middle diagram in Figure 2 shows the collector-emitter voltage U_T that is applied to semiconductor switch T2 and whose course corresponds to the control signal diagramed in the top part of the figure.

On the basis of the resonant circuit consisting of the elements L_R and C_R provided for current transformer 4, the collector current of the semiconductor switch T2 has the characteristic shown in the bottom diagram in Figure 2. This follows a sinusoidal function since the semiconductor switch T2 is enabled by the sudden voltage change at the base. The current then passes through its maximum according to the diagram and then subsides to zero. This value is maintained for a short period of

time before the semiconductor switch T2 is switched off. In the period of time between when the current drops to zero and the switching, the current is necessarily kept at zero.

The condition of lowering the current i_T to zero, which is illustrated in the bottom diagram in figure 2, before the disconnect process on semiconductor switch T2, can be achieved only if the following inequality is satisfied:

$$f_R = \frac{1}{2\pi\sqrt{L_R C_R}} < \frac{1}{2t_{ein}}$$

A minimum reserve of remaining time interval is required for the current to be reliably reduced to zero so that there are no switching losses.

Patent Claims

1. Arc welding device consisting of an inverter current source with a line-voltage-powered rectifier (1), an intermediate circuit (2), a current transformer (4) that is switched at the primary end and a rectifier (5) that is provided on the output end of the current transformer (4) and is connected to a welding device (9), where the current transformer (4) is switched by semiconductor switches (T1, T2) that are electrically conducting during a predetermined switching interval (T_{ein}), characterized in that a resonant circuit (L_R, C_R) is provided for the switched current transformer (4) and its resonant frequency (f_R) bears a relationship to the predetermined switching interval of the semiconductor switches (T1, T2) according to the following equation:

$$f_R = \frac{1}{2\pi\sqrt{L_R C_R}} > \frac{1}{2t_{ein}}$$

2. Arc welding device according to Claim 1, characterized in that the resonant circuit is a current resonant circuit where the current transformer is always switched at a time when the current

(i_T) in the resonant circuit has dropped to zero.

3. Arc welding device according to Claim 1, characterized in that the resonant circuit is a voltage resonant circuit, where the current transformer is switched at a time when the voltage (u_T) in the resonant circuit has dropped to zero.

4. Arc welding device according to one of the preceding claims, characterized in that the semiconductor switches (T1, T2) are IGBTs.

5. Arc welding device according to one of the preceding claims, characterized in that the inductive element (L_R) of the resonant circuit is formed by the leakage inductance of the current transformer (4).

6. Arc welding device according to one of the preceding claims, characterized in that the resonant circuit is located on the output side of the current transformer (4).

7. Arc welding device according to one of the Claims 1 through 5, characterized in that the resonant circuit is located on the input side of the current transformer.

8. Arc welding device according to one of the Claims 1 through 7, characterized in that the current transformer (4) is a single-ended converter.

9. Arc welding device according to one of the Claims 1 through 7, characterized in that the current transformer (4) is a double forward converter.

10. Arc welding device according to one of the Claims 1 through 7, characterized in that the current transformer (4) is a bridge converter.

11. Arc welding device according to one of the Claims 1 through 7, characterized in that the current transformer (4) is a half-bridge converter.

Plus 2 pages of drawings

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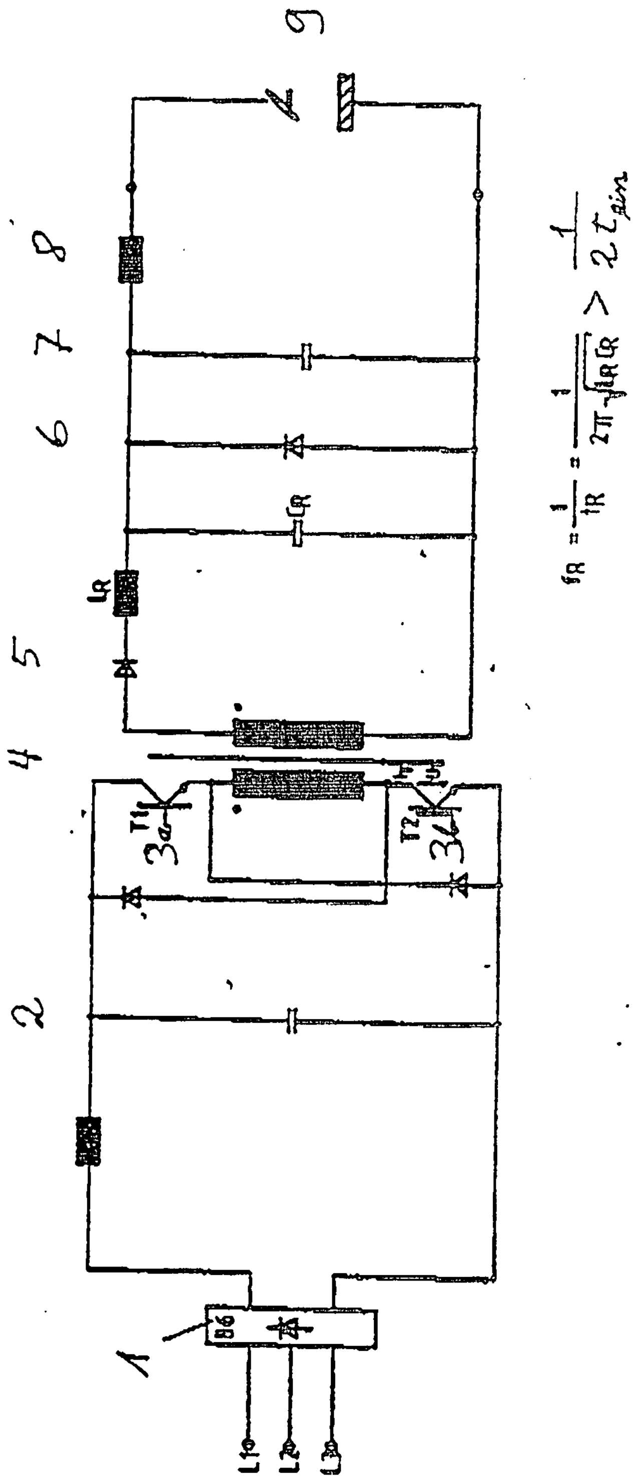

FIGUR 1

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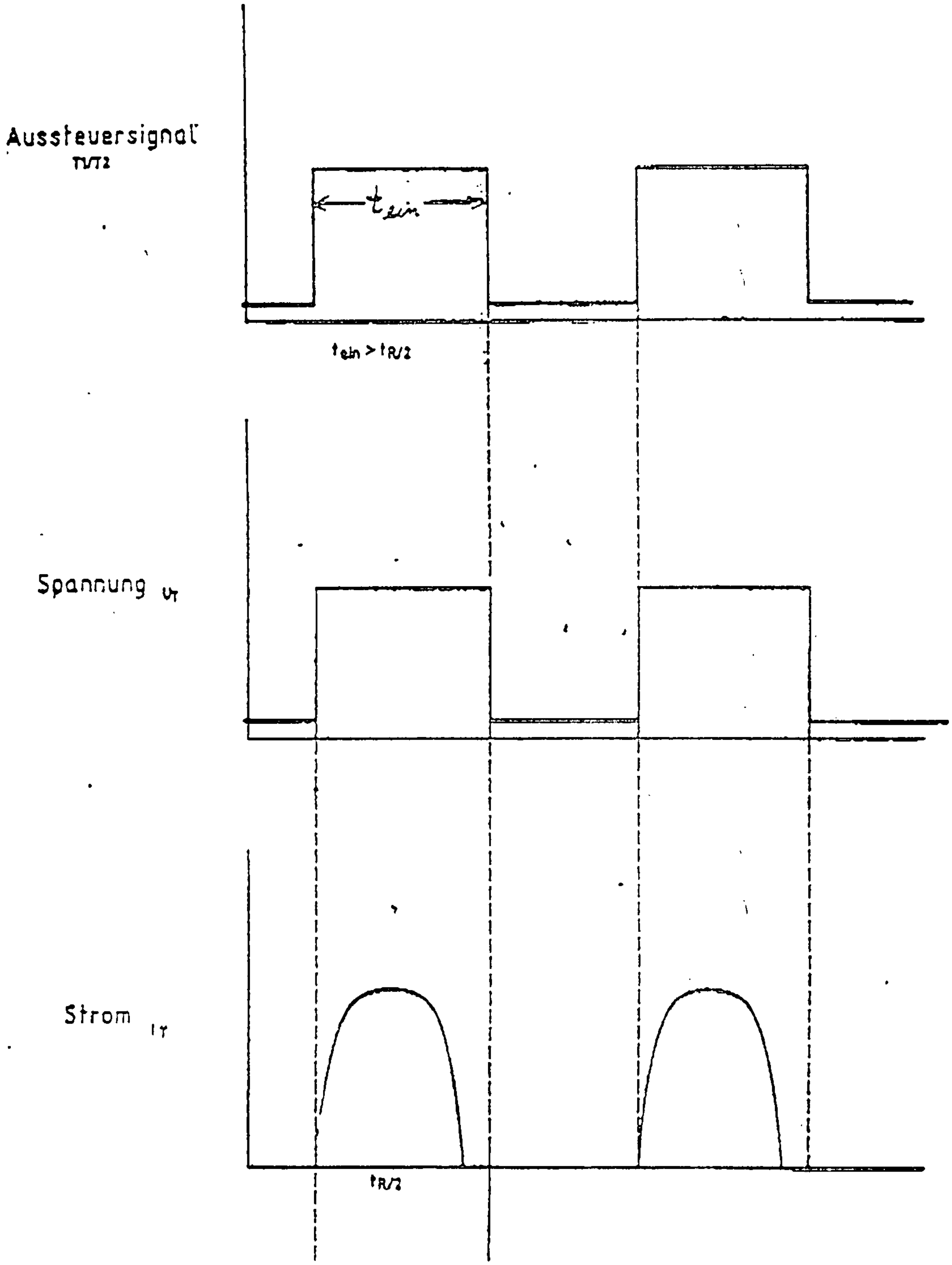

FIGUR 2 $f_R = \frac{1}{t_R} = \frac{1}{2\pi\sqrt{L_R C_R}}$

Aussteuersignal = control signal
Spannung = voltage
Strom = current